70017

DRAFT

Basalt

2957 grams

Figure 1: Photo of lunar basalt 70017 showing vugs and vesicles. Sample is about 10 cm across. Cube is 1 cm. NASA# S73-15723.

Introduction

Lunar sample 70017 is a vesicular, medium-grained, high-Ti basalt that was collected from the area near the Lunar Lander (figure 1). It was one of the last rocks collected from the moon and the astronauts made a speech about it referring to “the children of the world”. Subsequently, small pieces of it were distributed to all countries of the world. It has also been the subject of many science investigations (briefly summarized below).

Petrography

Longhi et al. (1974) describe 70017 as “a medium-grained hypidiomorphic granular high-Ti basalt with textural relations suggesting relatively slow cooling. Large, equant, subhedral grains of clinopyroxene (1-2 mm) enclose embayed ilmenite (figure 2). Plagioclase (up to 2 mm) is anhedral and poikilitically encloses clinopyroxene, olivine and ilmenite. Cristobalite is present in interstices between clinopyroxene, plagioclase and ilmenite.”

Roedder and Weiblen (1975) studied melt inclusions in ilmenite in 70017 and other Apollo 17 rocks and found evidence for silicate liquid immisibility.

Nord et al. (1974) determined that 70017 had a single-stage cooling history (<2 deg./hr.), by carefully studying the defect structure of pyroxene and plagioclase.

Mineralogy

Olivine: Olivine (Fo_{66-69}) is found in the cores of the large clinopyroxene grains and in plagioclase (figure 3).

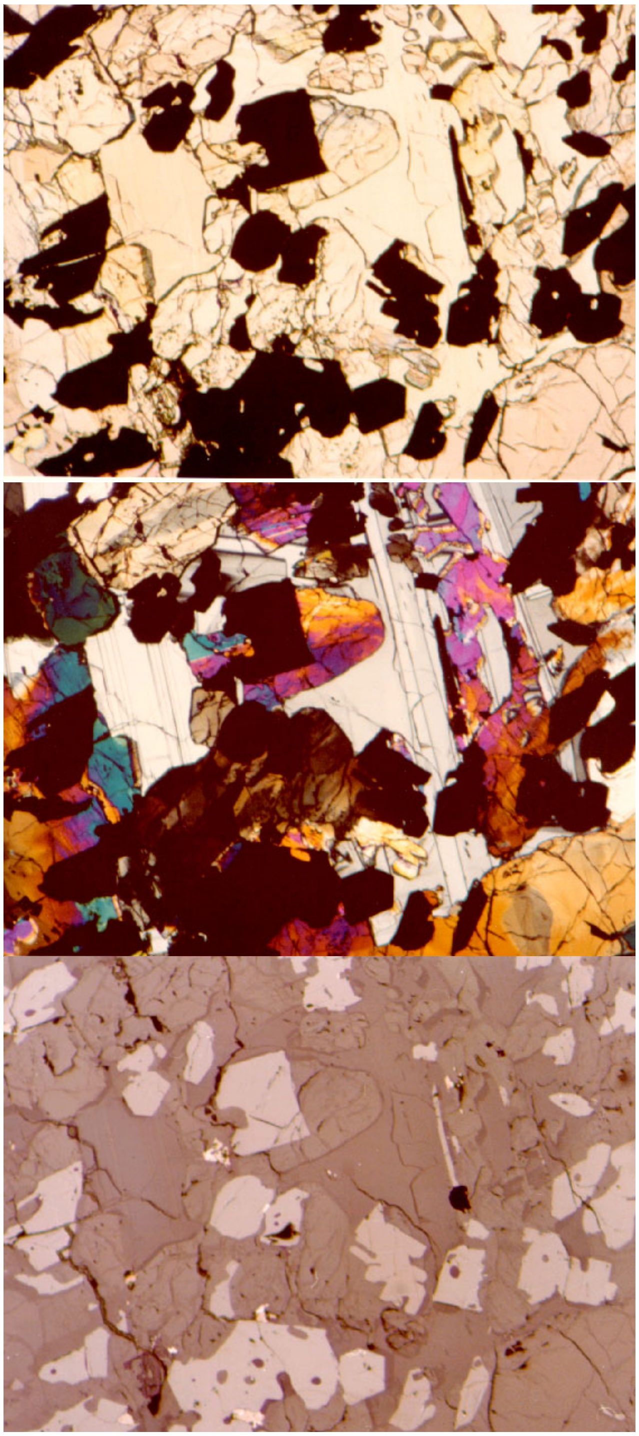

Figure 2. Three views of same area of thin section 70017,125 (transmitted light, crossed polorizers, and reflected light). Field of view is 2.5 mm. NASA # S79-26723-5.

Pyroxene: Pyroxene is abundant in 70017. Large pyroxene grains are zoned from subcalcic augite to pigeonite to Fe-rich (figure 4). Pyroxene cores contain up to 3.5% TiO_2 and 4.5% Al_2O_3 (Brown et al. 1973, Hodges and Kushiro 1974 and Longhi et al. 1974).

Figure 3: Partially polarized light photo of polysynthetic twinning in plagioclase poikilitically enclosing equant olivine and pyroxene crystals in 70017.

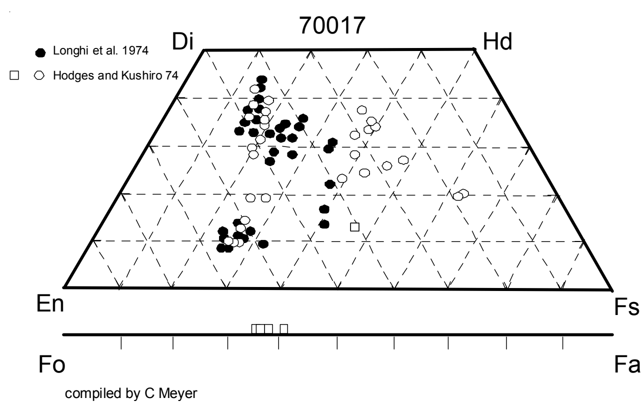

Figure 4: Pyroxene and olivine composition for mare base 70017 (data copied from Longhi et al. 1974 and Hodges and Kushiro 1974).

Sung et al. (1974) studied the ratio of $^{3+}Ti/^{4+}Ti$ in pyroxene – perhaps 30% is ^{3+}Ti!

Plagioclase: Longhi et al. (1974) measure plagioclase as An_{69-88}.

Opaques: Ilmenite is abundant and has exsolution of chromite and rutile (figure 5). Experiments show that

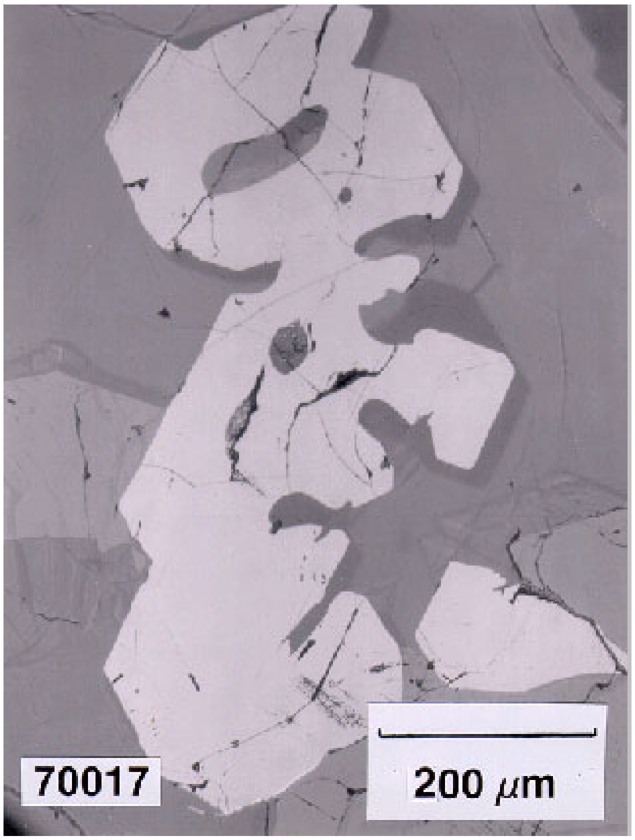

Figure 5: Reflected light photo of polished thin section illustrating habit of ilmenite in 70017.

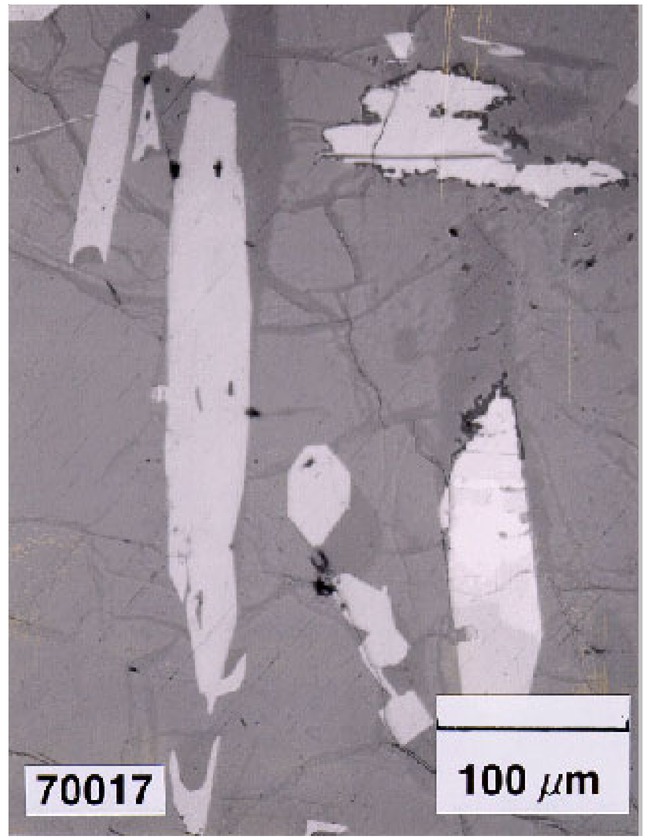

Figure 6: Reflected light photo of tan, barrel-shaped armalcolite in 70017. I t is hexagonal in cross section (center of photo), but tapered in the elongate direction.

armalcolite was an early phase, but it has mostly converted to ilmenite. Some relict armalcolite is found in pyroxene cores (figure 6). Small grains of chromite are reported in olivine (Hodges and Kushiro 1974). El Goresy and Ramdohr (1975) studied the opaque minerals in 70017 in order to determine the nature of subsolidus reduction producing elemental iron.

Mesostasis: A very complex mesostasis of glass, silica, troilite-iron, whitlockite and trace tranquillityite occurs in this rock. Silica is cristobalite (Hodges and Kushiro 1974, Roedder and Weiblen 1975) and has a characteristic cracked texture (figure 7).

Chemistry
The chemical composition of 70017 is given in table 1 and figures 8 and 9. It is typical of the other basalts returned from Taurus-Littrow. The chemical composition of high and low K melt inclusions is found in Roedder and Weiblen (1975).

Radiogenic age dating
Nyquist et al. (1975) and Schaeffer et al. (1977) have dated 70017 at 3.67 b.y. Note that the "ilmenite separates" are found to contain the most Rb (figure 10). The "ages" determined by Phinney et al. (1975) and Mattinson et al. (1977) were not convincing.

Mineralogical Mode for 70017

	Longhi et al. 1974	Brown et al. 1975	Roedder and Weiblen 1975
Olivine	1 %	0.9	0.4
Pyroxene	50	49.3	57.6
Plagioclase	26	25.4	19.8
Opaques	22	22.8	19.2
Fe	tr.		tr.
FeS	tr.		
Mesostasis	tr.	0.3	1.4
Silica		1.3	1.6

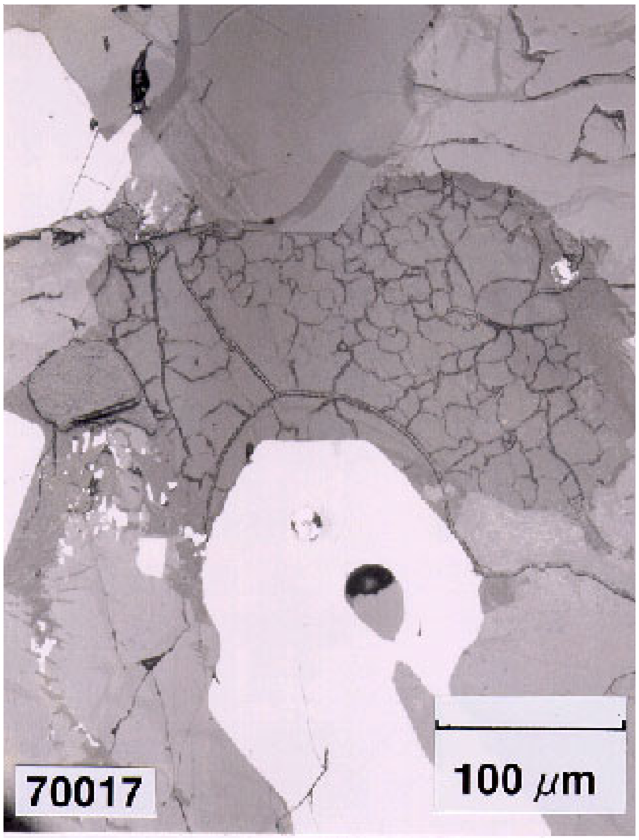

Figure 7: Reflected light photo of silica in 70017.

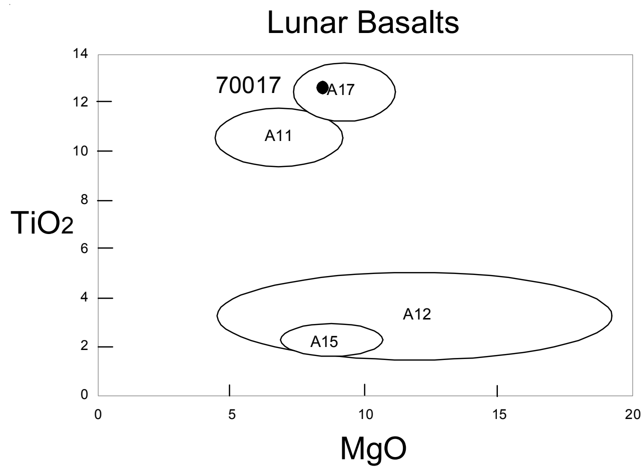

Figure 8: 70017 is a typical Apollo 17 basalt.

Cosmogenic isotopes and exposure ages

Phinney et al. (1975) determined an exposure age of 220 ± 20 m.y. for 70017.

Yokoyama et al. (1974) report that 70017 was apparently saturated with ^{26}Al.

Other Studies

Rutherford et al. (1974) studied the "liquid line of decent" for the cooling of a basalt with the composition of 70017 and found experimental evidence for "liquid immiscibility". Sato (1976) determined the insitu oxygen fugacity as a function of temperature (figure 11).

Petrowski et al. (1974) determined the concentration and isotopic composition of sulfur and carbon. Mayeda et al. (1974) reported the isotopic composition of oxygen.

Huffman et al. (1974) measured the Mössbauer spectra of 70017 (figure 12) and determined the amount of metallic iron (0.1%). Brecher et al. (1974), Nagata (1974), Stephenson et al. (1974) and Schwerer and Nagata (1976) studied the magnetic properties of 70017.

Hapke et al. (1978) and Osborne et al. (1978) used powered rock samples of 70017 to calibrate spectra that might be obtained from orbit.

Processing

Figure 13 show the initial cutting of 70017.

Neal and Taylor (1993) provide an extensive review of the work done 70017 in their catalog. Sixty thin sections were prepared from 70017. Thin sections of this rock are featured in the Lunar Petrographic Educational Thin Section Set (Meyer 2003).

Small pieces of this rock were given to all countries of the world.

Summary of Age Data for 70017

	Ar-Ar	Rb-Sr	U-Pb
Phinney et al. 1975	3.80 ± 0.03 b.y.		
Nyquist et al. 1975		3.67 ± 0.18	
Mattinson et al. 1977			3.7 b.y.
Schaeffer et al. 1977	**3.67 ± 0.12**		

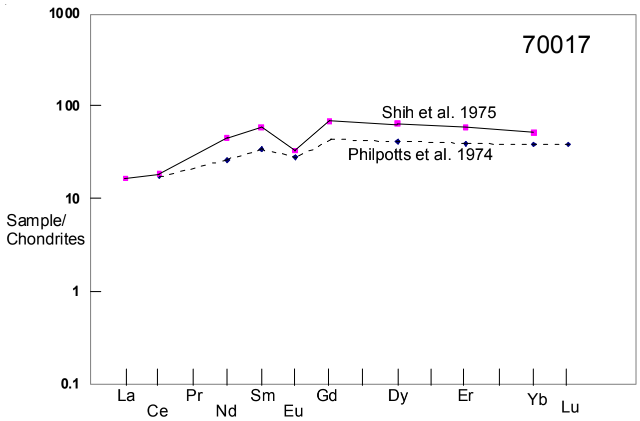

Figure 9: Normalized rare-earth-element pattern of 70017 (isotope dilution data from two different labs).

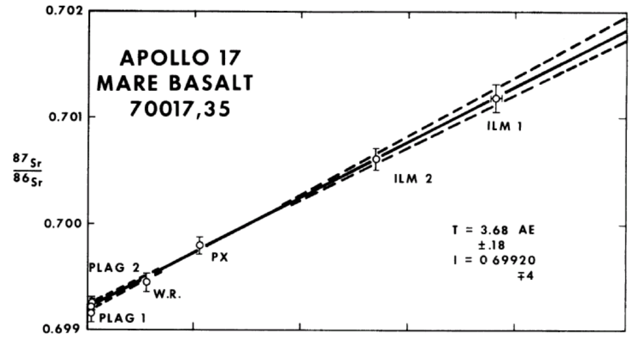

Figure 10: Rb-Sr isochron for 70017 (from Nyquist et al. 1974).

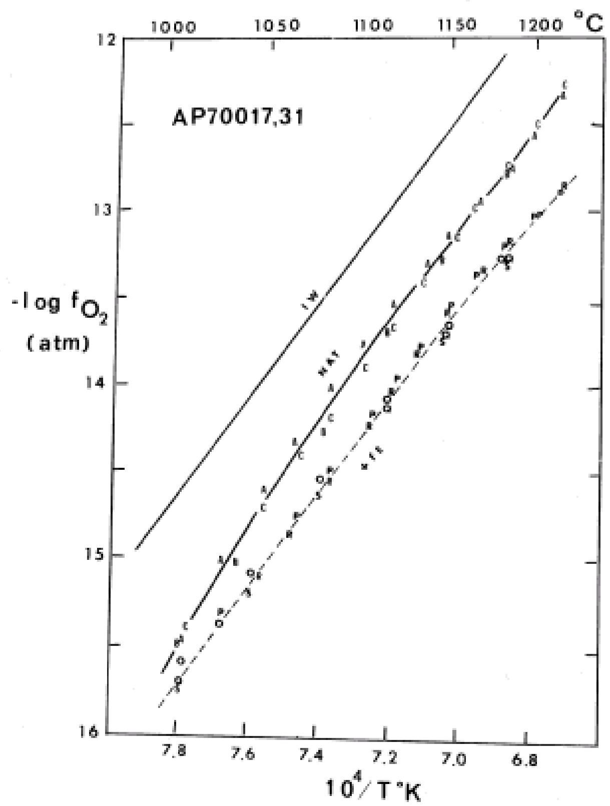

Figure 11: Oxygen fugacity vrs. temperature for 70017 (from Sato 1976).

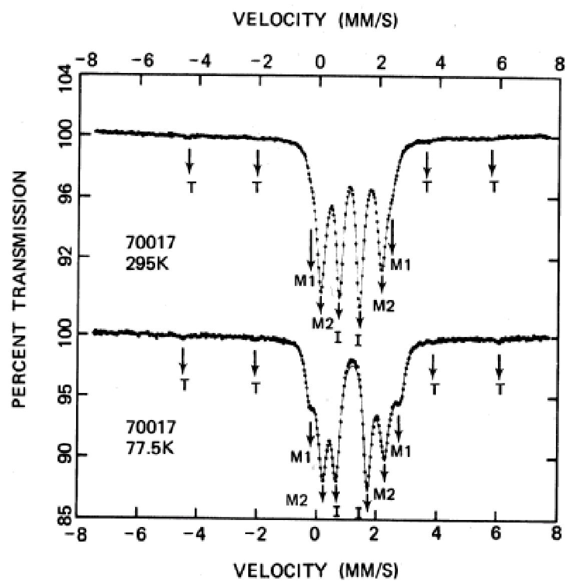

Figure 12: Moessbauer spectra of 70017 (from Huffman et al. 1974)

Table 1. Chemical composition of 70017.

reference	Rose 74			Brunfelt 74		Miller 74	Nava 74	Rhodes 74		Duncan 74	Philpotts 74	Shih 75		Dickinson 89	
weight															
SiO2 %	38.8	38.68	(a)			38.52	38.8	38.07	(c)	38.37					
TiO2	12.84	13.75	(a)	13.58		12.21	12.44	13.1	(c)	12.83					
Al2O3	8.54	7.4	(a)	9.47		9.07	9.73	8.79	(c)	8.78					
FeO	18.12	18.77	(a)	18.32		18.19	17.6	18.07	(c)	18.71					17.5
MnO	0.24	0.25	(a)	0.254		0.233	0.232	0.27	(c)	0.247					
MgO	10.16	10.45	(a)	9.13		11.95	9.89	9.81	(c)	9.41					
CaO	10.56	10.05	(a)	11.48		10.36	10.04	10.3	(c)	10.43				7.14	13.4
Na2O	0.33	0.34	(a)	0.405		0.405	0.43	0.4	(c)	0.43				0.32	0.43
K2O	0.07	0.07	(a)	0.044			0.036	0.04	(c)	0.047		0.058	(e)		
P2O5	0.04	0.04	(a)				0.048	0.05	(c)	0.052					
S %								0.15	(c)	0.175					
sum								99.05							
Sc ppm	80	77	(a)	87	(b)							82.7	(e)	75	78
V	98	80	(a)	156	(b)					146					288
Cr	3350	3350	(a)	3550	(b)		3080			3948		3490	(e)		
Co	32	32	(a)	20.6	(b)					18		14.5	(e)	132	22
Ni	<1	24	(a)	<10	(b)					<3					
Cu	28	84	(a)	2.8	(b)					<3					
Zn	<4	<4	(a)	2	(b)					<2					
Ga	5.8	5.4	(a)	3.1	(b)									21	
Ge ppb														1.7	1.9
As															
Se															
Rb	0.9	0.7	(a)	0.4	(b)					1.2	0.28	0.299	(e)		
Sr	217	155	(a)	127	(b)					166	168	153	(e)	172	306
Y	94	100	(a)							71.2	32				
Zr	254	250	(a)							218	223	177	(e)		138
Nb	23	18	(a)							18.5					
Mo															
Ru															
Rh															
Pd ppb															
Ag ppb															
Cd ppb															
In ppb															
Sn ppb															
Sb ppb															
Te ppb															
Cs ppm				0.3	(b)										
Ba	250	180	(a)	55	(b)					83	43			78	68
La	<10	<10	(a)	4.11	(b)							3.99	(e)	4.6	4.4
Ce				13.5	(b)						10.7	11.3	(e)	16	15
Pr															
Nd											12.1	20.7	(e)	20	14
Sm				7.53	(b)						5.13	8.8	(e)	6.7	*71*
Eu				1.77	(b)						1.62	1.91	(e)	1.6	1.7
Gd												13.9	(e)		
Tb				1.77	(b)									2.5	2
Dy				13.8	(b)						10.2	16.1	(e)		
Ho															
Er											6.31	9.54	(e)	0.71	
Tm															
Yb	7.7	8.3	(a)	6.3	(b)						6.25	8.68	(e)	8.2	6.9
Lu				1.15	(b)						0.954			1.3	1.1
Hf				8	(b)									7.4	6
Ta				1.55	(b)									1.8	1.5
W ppb				0.075	(b)										
Re ppb															
Os ppb															
Ir ppb															
Pt ppb															
Au ppb															
Th ppm				0.17	(b)									*4.8*	0.14
U ppm				0.088	(b)										

technique (a) combined XRF, OES, chemical, (b) INAA, (e) IDMS

Figure 13: Sample 70017 after intial sawing. Note high proportion of vesicles. NASA# S73-28689